The Potential of Agent-Based Simulation for Decision Support in Politics: The Case of Multicultural Societies

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ABSTRACT

According to PARSON's structural functionalism, politicians are in charge of establishing and preserving a functional society. Political decisions have to be effective regarding such functionality. Due to globalization and numerous worldwide trouble spots, more and more people leave their home countries. They concentrate themselves in cities like Berlin or New York. Such societies are deemed as "multicultural" and exhibit an increasing space-time complexity. Additionally, such societies challenge politicians to make effective political decisions. For one thing, politicians have to make decisions under time pressure as well as with insufficient information in both quantity and quality. For another thing, the perception of societies' space-time complexity by politicians is limited. As a consequence, politicians need decision support to increase the quality of their decisions. Against this background, this paper investigates the potential of agent-based simulation for decision support in politics, in particular in the context of multicultural societies.

Keywords

Decision support, agent-based simulation, politics, multicultural societies.

INTRODUCTION

Societies, as the primary investigation object of this paper, consist of human beings with different characteristics. They differ e.g. regarding the 'total number of society members' and the 'number of different cultural groups'. From the perspective of social sciences, each member of the society can be described by characteristics like 'homophily' against other members of the society or 'adaption propensity' to cultural or ethnic values (Schelling, 1971). Especially societies in cities like Berlin and New York change greatly over time. They develop from cities with only a few ethnic or cultural groups to cities with many different members from all over the world. Those societies can be called "multicultural" or strive to build a multicultural society, which is tolerant toward all cultural groups that are part of that society and which nurture social interaction between the different groups. This development is influenced by macro-economic development. On the one hand, globalization intensifies the movement from underdeveloped countries to countries with strong economic power. On the other hand, numerous trouble spots (e.g. as a result of wars, ethnical and political persecution) motivate or force people to leave their home countries (Skeldon, 2010; Taran and Geronimi, 2003). Due to political influence and personal preferences, such people concentrate in cities like Berlin and New York and consequently, such developments change the structure of societies and the behavior within the societies significantly and confront politicians with new challenges.

According to PARSON's structural functionalism (Parson, 1971), politicians are in charge of establishing and preserving a functional society. One necessary condition for its functionality is the interaction between each member of the society. Political decisions have to be *effective* regarding such functionality. Without any political intervention, societies tend to show *phenomena* that prevent functionality, e.g. "isolation" and "parallelism". In the case of "isolation", societies with only a few different cultural groups consist of members who are unwilling to interact with members of the other cultural groups (Blau, 1977). In the case of "parallelism", the society consists of many different cultural groups, whereas the individuals do not sustain social order by frequent interaction even though they each hold the same cultural values and meanings (Blau, 1977).

From the perspective of *decision support,* politicians have to cope with barriers which negatively affect the identification and implementation of effective political actions:

- *Barrier (a) – "time pressure of decisions"*: Analogous to *management theory*, politicians are political "managers", planning political actions and controlling their implementation. Planning helps decision makers increase their decision quality, whereas especially planning takes much time. In contrast, politicians often have to make decisions under high time pressure *without* planning, which is called "extemporization" (Wild, 1982).
- *Barrier (b) – "insufficient information quantity and quality"*: One necessary prerequisite for effective political decisions is information about a society. Such information has the characteristics of "quantity" ("Is the necessary information available for the decision maker?") and "quality" ("Is the available information adequate for the decision?"). The necessary quantity and quality of the information depends on the investigation object and investigation objectives.

Besides these barriers, politicians are – like every subject – confronted with neurophysiological limitations (Glasersfeld, 2002; Maturana, 1992). Due to being part of the *space-time* (Disalle, 2008), a society's structure is not fixed nor offers identical behavior over a long time period. The politician's subjective perception of such developments is limited due to further barriers:

- *Barrier (c) – "space-complexity"*: Politicians' reality exhibits high structural and behavioral complexity at any point in time. Societies consist of thousands or millions of members and different relationships with each other (structural complexity). Furthermore, each member of a society has his or her own unique behavior (behavioral complexity). Politicians, as individual subjects, have strong limitations to cope with such complexities. If politicians are not able to recognize patterns of structure or behavior, they face "unstructured", "ill-structured" or "semi-structured" problems (Simon, 1973) or "chaos" (Alligood, Sauer and Yorke, 1996).
- *Barrier (d) – "time-complexity"*: The structure and the behavior (as well as structural and behavioral complexity) of investigation objects are time-dependent and may change over time (Disalle, 2008). Further, there are several delays from the moment of problem recognition to the moment when political interventions take effect. As a consequence, the assumptions about the system on which political interventions are based may be inappropriate or out of date.

In conclusion to the social science and decision support perspectives above, we postulate the following *analysis hypothesis (AH)*, representing the research problem:

AH: "Politicians in the field of multicultural societies need support for the derivation and valuation of political actions. Otherwise, politicians run the risk of making decisions with insufficient decision quality."

First construction idea – "decision support systems": To solve the analysis hypothesis, we take the theory of *decision support systems* (DSS) into account (e.g. Alter, 1980; Sprague and Carlson, 1982; Sprague and Watson, 1993; Turban, Aronson, Sharda, Delen and Liang, 2010). DSS are software tools (cf. Figure 1) which support decision makers in unstructured, ill-structured or semi-structured problems (Sprague and Watson, 1993). Besides the "dialog" and "data base" component, DSS are characterized especially by providing *methodological* support (DSS component "method") to a decision maker and allow a *model-driven* investigation of an investigation object (DSS component "model") (similar Power, 2002; Power, 2004; Scott Morton, 1971). The main objectives of DSS are "reducing the decision time" and "increasing the decision quality" (Sprague and Carlson, 1982). More precisely, DSS has the potential to support politicians to cope with the barriers mentioned above. In conclusion, we postulate the *construction hypothesis CH_1*:

CH_1: "The concept of DSS has the potential to support politicians preparing their political actions in multicultural societies."

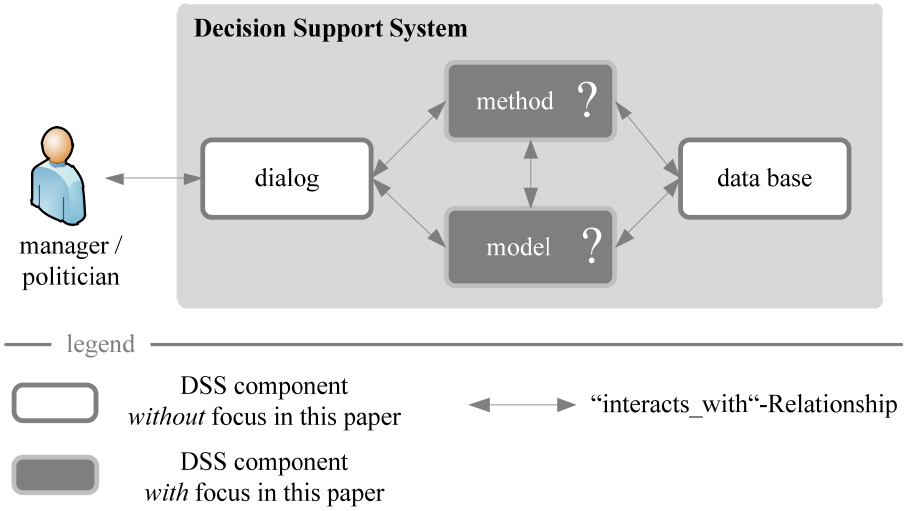

Figure 1. Paper's Focus with Respect to a Generic Structure of a DSS

The remainder of the paper is structured as follows. The next section introduces political functional requirements and foundations for the configuration of the DSS component "method". This section evaluates typical "elementary investigation procedures" of science as well as political practice to motivate the investigation procedure "simulation experiments" and concept of agent-based simulation (ABS). Afterwards, an agent-based simulation model is designed and validated based on the approach by SCHELLING (Schelling, 1969, 1971, 1978), which configures the DSS component "model". The model's applicability and its potential for decision support are shown by two cases called "Berlin" and "New York". Furthermore, the behavior of the simulation runs is discussed in order to derive the decision support perspective and political implications. Finally, we summarize the paper, address potential benefits and limitations of the approach and give an outlook on our future research.

METHODOLOGICAL FOUNDATION: INVESTIGATION PROCEDURES, INVESTIGATION OBJECTS AND GOAL ACHIEVEMENT

To investigate the functional requirements (*Req*) for the DSS component "method", we analyze the typical tasks of politicians more thoroughly. Analogous to managers, politicians are essentially *planners*. They plan political actions, control the implementation and give feedback on the results (Mintzberg, 2011; Wild, 1982).

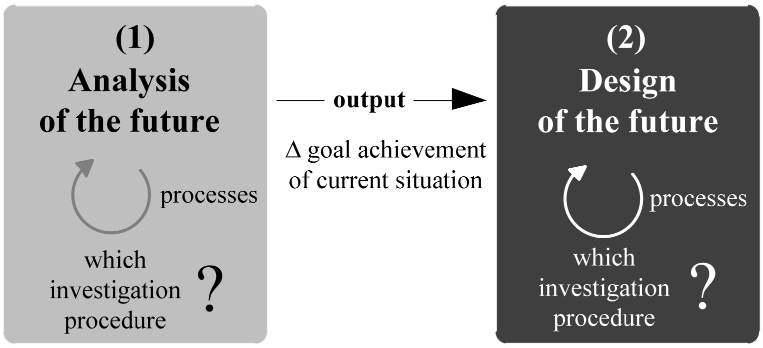

Figure 2. General Activities within the Task "Planning"

The task "planning" consists especially of the following "general activities" (Mintzberg, 2010; Wild, 1982) (cf. Figure 2):

1.) *"Analysis of the future":* Politicians face the question: *"What are the possible futures of a society without any political actions?"* This question corresponds to the investigation objective "prognosis" (Req_1). Output of the "future analysis" is the discrepancy (Δ) of the future from the current situation and the desired situation *without* any changes to the investigation object.

2.) *"Design of the future":* If the goal achievement is not optimal or not satisfying, politicians face the question *"What are possible political actions to improve the goal achievement?"* (objective "design", *Req_2*). Before being able to answer the question, politicians need a clear understanding of the investigation object (objective "explanation", *Req_3*). Later on, possible alternatives are evaluated: *"What are the consequences of the possible political actions?"*. This question corresponds to the objective "prognosis".

elemental investigation procedure	min. **implementation range** max.	min. **maximum of goal achievement** max.
observation	■■■□	■■□□
experiment	■■□□	■■■□
creativity procedure	■■■■	■□□□
algorithms (heuristic, approximate, exact)	■□□□	■■■■

legend

■ fulfilled □ not fulfilled

Table 1. Comparison of Elemental Investigation Procedures[1]

To fulfill these functional requirements of the DSS component "method", we have to identify appropriate *investigation procedures* that support the functional requirements above (cf. Figure 2). Investigation procedures ideally transfer elements of an input set *IN* to an output set *OUT* using a mapping relationship *IN→OUT*. In general, four *elementary types of investigation procedures* are available (Ferstl, 1979):

- *Observations:* The investigation procedure "observation" analyzes the effects *OUT* of the investigation object on its environment. A necessary prerequisite of the application of this investigation procedure is the availability of appropriate *sensors* to perceive the effects. *IN* cannot be manipulated. Since observations may require enormous time efforts, the barrier (a) is intensified. The contribution to barriers (c) and (d) are weak. In case of an investigation objective "explanation" (*Req_3*), the barrier (b) is reduced.
- *Experiment:* The investigation procedure experiment analyzes *real systems*. The investigation object is affected by *experimental factors* (*IN*), which can be manipulated, and *unregulated factors* (*IN*), which cannot be manipulated or are insignificant. During an experiment *IN* is varied, and the reaction of the investigation object (*OUT*) is observed. A necessary prerequisite of the application of this investigation procedure is the accessibility and the ability to influence the investigation object. Experiments have the potential to fulfill *Req_1* and *Req_3*, but a real system is needed.
- *Creativity procedure:* A necessary prerequisite of the application of this investigation procedure is the subject's capability to associate future developments or problem solutions. The investigation problem (*IN*) is presented to a subject as a "black box", which seeks a problem solution (*OUT*) by cogitation. Creativity procedures can be applied to every investigation objective (fulfills *Req_1, Req_2* and *Req_3*), whereas the mapping of *IN→OUT* is fully subjective and does not reduce the barriers (c) and (d). Barriers (a) and (b) depend on the investigation objectives and subjects' characteristics.
- *Algorithm:* Algorithms are investigation procedures for the investigation of *formal systems*. An algorithm is a description of necessary finite steps (*IN→OUT*) to transform a given input (*IN*) into a desired output (*OUT*). *Exact algorithms* calculate an *optimal* solution. *Approximate algorithms* calculate *non-optimal* solutions, in which the difference between the solution and the optimum is known. *Heuristic algorithms* are used if exact or approximation

[1] Note that the assessment of the investigation procedures is only *qualitative* and *coarse-grained*.

algorithms are not applicable. Such algorithms calculate *allowable* solutions, whereas the goal achievement cannot be determined. If formalization is possible, algorithms have the potential to fulfill Req_1 and Req_3 as well as to reduce *all* the barriers described above.

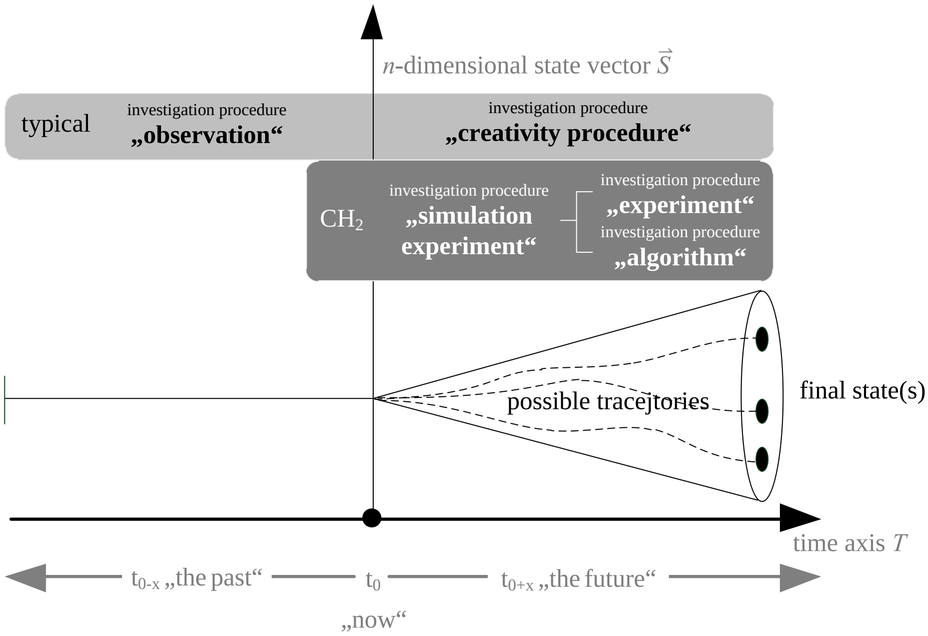

Figure 3. “Time-Range” of Investigation Procedures on Time Axis *T*[2]

Table 1 summarizes the findings. For a closer analysis, the vector of interesting states $\vec{S}$ of an investigation object is contrasted with a time axis *T* (cf. Figure 3). Because of the long-term investigation, *T* is ordinal scaled and shows the time point t_0 signifying “now” and the time intervals t_{0-x} signifying “the past” as well as t_{0+x} signifying “the future”. Starting at t_0, possible parameterizations of a simulation model lead to several trajectories of an investigation object within space-time. At t_{0+x}, a final state is reached, which embraces the vector of interesting states $\vec{S}$ of the investigation object. All trajectories represent a typical “cone”. In politics, common investigation procedures to analyze the past (t_{0-x}) are *observations*. Politicians gain information about the society using statistics and reports to get a comprehensive understanding of the investigation object (Req_3). To analyze (Req_1) and design the future (Req_2), politicians typically use *creativity procedures*. According to the findings above, even the best goal achievement is only minimal (cf. Table 1). Furthermore, no barrier is reduced, so that there is the danger of obtaining *ineffective* political actions. To improve the current situation, we propose the following construction ideas and construction hypotheses:

Second construction idea – “simulation experiment”: An investigation procedure “simulation experiment” is the combination of the investigation procedure “experiment” and “algorithm”, which allows the use of the strengths of both investigation procedures while eliminating their weaknesses. Although the investigation procedure “experiment” analyzes real systems, the combination with the investigation procedure “algorithm” allows a model-driven investigation with formally specified simulation models. The behavior of a simulation experiment is described by the following components (Ferstl, 1979):

(1.) *Experiment:* Typically non-automated determination of the experimental factors (*IN*) that parameterizes the investigation object “simulation model”.

(2.) *Algorithm:* Automated processing of a simulation algorithm “on” the simulation model and observing the behavior (*OUT*). The algorithm determines the relationship between *IN* and *OUT* (*IN*→*OUT*). The realization of the algorithm depends on a concrete simulation approach (cf. third construction idea).

[2] Note that for reasons of simplification the n-dimensional state vector $\vec{S}$ is represented by a single axis.

The main advantage of this combination is the potential for higher goal achievement instead of using only creativity procedures for prognoses. Most of the task “prognosis” can be fully automated, which would improve the capability of managing barriers (c) and (d). In conclusion, we postulate the following construction hypothesis:

CH_2: “Simulation experiments as part of a DSS component “method” increase the decision quality.”

Third construction idea – “Agent-based Simulation”: Several simulation approaches exist for a model-driven investigation of the investigation object’s behavior. According to JACOB/SUCHAN/FERSTL (2010), discrete-event driven simulation (DEVS) (Law, 2006) is suitable for micro-analysis problems. Such problems focus on object systems with fine granularity (e.g. mobile and stationary entities), short time horizons (e.g. seconds, minutes or hours) and support investigation objectives like processing times and machine capacities (Jacob, Suchan and Ferstl, 2010). Instead, time-continuous simulation like System Dynamics (SD) (e.g. Forrester, 1961; Sterman, 2000) should be used in the case of macro-analysis problems. Such problems focus on investigation objects with coarse granularity (only sets of objects), long time horizon (e.g. days, months or years) and support investigation objectives like system’s behavior in general (e.g. “stability” or “instability”) or the viability of the system (Jacob et al., 2010). In contrast to DEVS and SD, ABS (Gilbert, 2008) focuses on both, the short term micro-behavior of single entities (the “agents”) *and* the long term macro-behavior of the whole entities. The investigation objective is the identification of “emerging phenomena” (Gilbert, 2008). In conclusion, we derive the following construction hypothesis:

CH_3: “Agent-based simulation as part of a DSS component “method” increases the decision quality.”

Before starting the model construction, we give a brief literature overview. Publications available broach only isolated issues of the analysis and construction hypotheses. For example, FOSSET (1999) investigates the potential impact of ethnic preferences and social distance dynamics on segregation using ABS (Fosset, 1999, 2006). COLLINS and TRAJKOVSKI (2006) use ABS to impart capabilities on multiculturalism in educational settings (Collins and Trajkovski, 2006). Furthermore, MUŽÍKOVÁ (2011) discusses SCHELLING’s model in context of actual multiculturalism problems in Europe (Mužíková, 2011). Nevertheless, none of the identified publications investigate the combination of this paper’s hypotheses.

DESIGN OF THE SIMULATION MODEL (BUILDTIME)

To simplify the model construction and increase the model’s validity, we take the SCHELLING model (Schelling, 1969, 1971, 1978) into account. The SCHELLING model was used to explain the high degree of segregation between black and white city residents in the 1970s. Due to the similarity of the SCHELLING model to the paper’s investigation objectives, we use it for the following *fourth construction idea*.

Preparing the Simulation Model’s Structure

The agents of the SCHELLING model are characterized by two attributes: ‘Skin color’ and ‘homophily’. Homophily (Blau, 1977) refers to the desire of agents to live in a neighborhood in which a certain share of neighbors (or more) has the same skin color as the respective agent. To find such a neighborhood, agents move within a square lattice, in which each square stands for a possible home. The simulation terminates once every agent is satisfied. The surprising insight from the SCHELLING model is that, in the final population, the average number of similar neighbors significantly exceeds agents’ homophily. SCHELLING concludes that a high degree of racial segregation can arise although individuals are relatively tolerant (Schelling, 1971).

The SCHELLING model and related versions have been investigated in a variety of studies (Clark and Fosset, 2008; Fagiolo, Valente and Vriend, 2007; Pancs and Vriend, 2007). Due to its simplicity, its explanatory power and the robustness of the results, the SCHELLING model can still be regarded as an appropriate basis to tackle research questions on segregation and integration. Yet, as a drawback of the SCHELLING model, its fundamental assumption – the distinction between two groups of people with different skin colors – cannot be maintained for multicultural societies in which various cultural groups interact with each other. For this reason, we have developed an adaptation of that model. The adaptation relates to the following two dimensions:

- *Agent attributes*: Modern multicultural societies consist of a variety of different cultural groups which do no longer differ in their skin color but in their cultural identity. As a consequence, we reinterpret skin color as ‘cultural identity’. Furthermore, in contrast to skin color, cultural identity must be assumed to change. By definition, cultural identity of individuals is formed by the social environment with which they interact. If this environment changes, cultural identity may adapt, too. To account for this fact, we implement the attribute ‘adaption propensity’, which specifies the likelihood that an unhappy agent adopts the cultural identity of one of the neighbors instead of moving on.

- *Rules of behavior*: The skin color of a person can be identified without social interaction and from a distance. In contrast, cultural identity can be recognized only through personal interaction. Considering this, we assume that agents do not instantly find an appropriate spot to live but search for it, which implies trial and error: If an agent is unhappy, the agent moves to a random spot, which is not too far from its original position. There, an agent stays one round to interact with its neighbors, to recognize their social identity and to check if the new neighborhood complies with his homophily. As long as this condition is true, the agent stays at this spot, otherwise he continues to move.

To sum up, the model has three central parameters: *iniGroups* – the number of different groups in the initial population; *homophily* – the minimum ratio of neighbors with another social culture which the agent can accept; and *adaProp* – the likelihood that an unhappy agent adapts to the culture of one of his neighbors. As a result of the considerations, we propose the *fourth construction hypothesis* (CH_4):

CH_4: "SCHELLING's model is suitable to be the 'reference model' to an adaptation to problem settings in multicultural societies."

Validation of the Simulation Model

The original model by SCHELLING (1971) is characterized by a relatively high level of abstraction and aims at the qualitative explanation of a real phenomenon (the high level of segregation in American cities). The model is regarded to be validated in a qualitative way as it reproduces this phenomenon. Principally, a high tendency of social clustering is also observed in multicultural cities (Andersen, 2003; Huttmann, Blower and Saltman, 1991; Musterd, 2006). Therefore, the extended model should be able to mimic this behavior and thus, the behavior of the SCHELLING model.

To test the tendency of social segregation, we vary those independent variables that are new in the extended model (*iniGroups* and *adaProp*) while keeping *simWanted* constant to 0.5 – the setting in the original SCHELLING model. Ideally, for every setting of independent variables, the segregation level (*S*) should be equal to the one observed in the SCHELLING model. The latter value results from *iniGroups = 2* and *adaProp = 0* and is about 60%. The deviance from this reference value can be interpreted as an *error*. Figure 4 shows the resulting *error surface*, which is an almost perfect plane on a z-level near 60%. In other words, it neither matters how diversified the initial population is nor how strongly agents tend to adapt to their social environment: In equilibrium, the same high degree of segregation is achieved. In conclusion, the extended model replicates the great tendency towards segregation in a very similar way as the original model by SCHELLING.

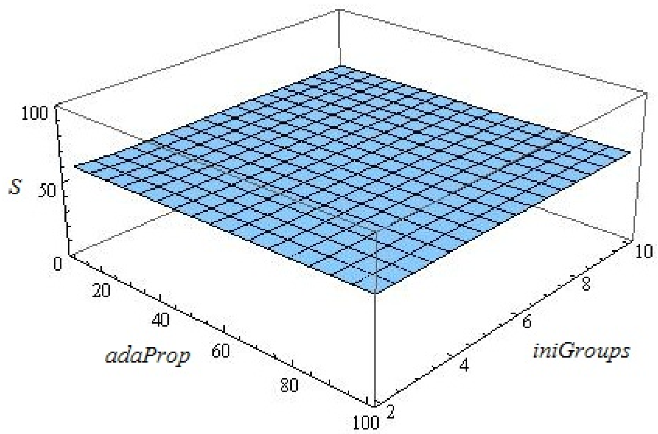

Figure 4. Error Surface of the Simulation Model According to SCHELLING's Model

APPLICATION OF THE SIMULATION MODEL TO THE CITIES OF "BERLIN" AND "NEW YORK" (RUN TIME)

To illustrate how the model provides decision support for multicultural societies, we look at two types of cities called "Berlin" and "New York". The goal is to explore how these cities might evolve in the future, to identify *emerging phenomena* and to derive relevant insights for political decision support. Compared to "New York", "Berlin" is characterized by relatively few, albeit large, cultural groups (*iniGroups* = 3). The homophily of people is moderate (*homophily* = 6/8 or 0.75%). "New York" consists of a multitude of different cultural groups (*iniGroups* = 10) which are relatively small.

Homophily is relatively low (*homophily* = 5/8 or 0.625%). With 50%, *adaProp* is equal in both cities. Figure 6 illustrates the parameter settings.[3]

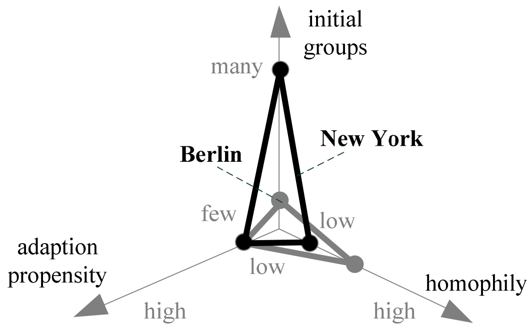

Figure 6. Overview of Simulation Experiment's Parameters

As dependent variables, we define (I) the time until convergence has been reached, (II) the number of different cultures in the final population, (III) its cultural heterogeneity and (IV) its degree of segregation. As the indicator for (III), we use BLAU's *heterogeneity index* (Blau, 1977). BLAU computes the heterogeneity H of a population as follows:

$$H = 1 - \sum_{k=1}^{N} s_k^2, \tag{1}$$

where s_k denotes the ratio of agents of a particular group (ethnic identity) k in the population, and N is the number of different groups of which at least one agent exists. The higher H is, the more multicultural the population (by definition, $H \in [0;1]$).

The degree of segregation (IV) can be measured by a variety of indicators (cf. Pancs and Vriend, 2003 for an overview). For the purpose of comparability, we use the same indicator as SCHELLING (1969, 1971) who computes the average percentage of similar neighbors, S:

$$S = \left\{ \frac{1}{N} \sum_{i=1}^{N} \frac{\alpha_i}{\mathrm{A_i}} * 100 \qquad with\ \frac{\alpha_i}{\mathrm{A_i}} = 0 \leftrightarrow \mathrm{A_i} = 0, \right. \tag{2}$$

where α_i is the number of similar neighbors, and A_i is the total number of neighbors of agent i. A greater neighborhood (nbhd.)-similarity S indicates a greater degree of segregation of the population.

The Case "Berlin"

Figure 7 shows a typical simulation run of the case "Berlin".[4] The initial state and the values of respective indicators are displayed on the left. The final state is displayed on the right. "Ticks" denotes the corresponding simulation step. Figure 7 shows how the micro-behavior of individuals produces a specific behavioral pattern of the social system as a whole. After 78 simulation steps, every agent has achieved the state of finding a home which matches the ratio of different neighboring groups an agent is willing to accept. Notably, with 99.8% compared to 5/8 (62.5%), the average share of neighbors with the same cultural identity significantly exceeds the agent's desire for similarity. In other words, we find a relatively low preference for similarity is needed to produce a high degree of cultural segregation on the macro level. This emerging phenomenon is similar to the finding of SCHELLING (Schelling, 1969, 1971, 1978). As a benefit of our multicultural model, we can also observe the degree to which cultural assimilation has occurred. In the experiment that is displayed, one of the initial three groups has disappeared completely, that is, the respective individuals have adopted other cultural identities.

[3] Note that the two cases are not based on a *quantitative* empirical fit to the real cities Berlin and New York but serve for the *qualitative* illustration of emergent phenomena. The greater cultural diversity of New York can be verified by the demographic data of the two cities (for data see U.S. Census Bureau, 2010; Vollmer, 2010).

[4] The simulation experiments are conducted with the simulator "NetLogo".

However, the other two groups are still relatively large. The culture of the final population seems to be split quite equally into these two groups. Due to the cultural adaptation of individuals, the heterogeneity of the population has decreased slightly, from 66.7% to 49%.

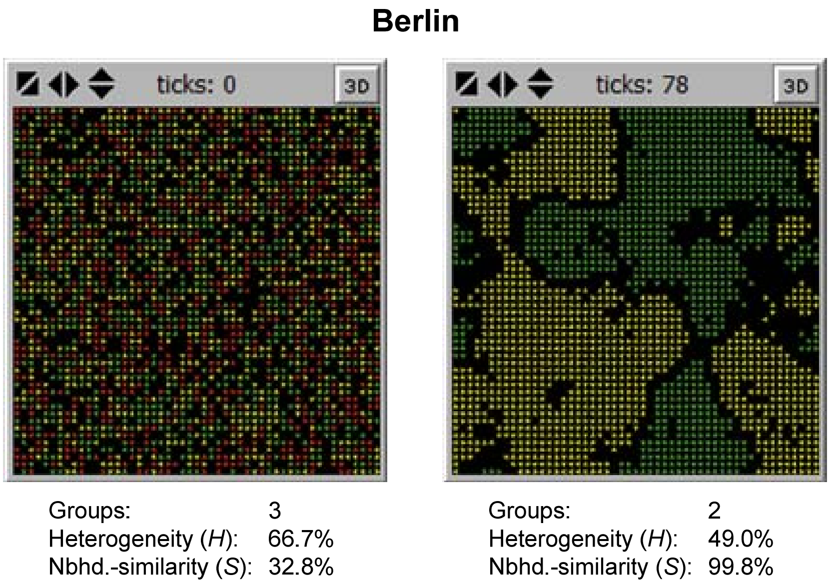

Figure 7. Overview of the Simulation Experiment "Berlin"

The Case "New York"

Figure 8 displays a typical simulation run of the case "New York". With 91.0% compared to 66.7%, the cultural heterogeneity of the initial population is significantly greater in New York than in Berlin. Further, the homophily of individuals is lower. Both factors suggest that in the final state, the heterogeneity of the population will remain significantly higher than in Berlin. Surprisingly, the simulation experiment refutes this hypothesis.

In its final state, the heterogeneity of the population has dropped significantly to 17.3%. Out of the initial ten cultural groups, only four remain, with one group dominating the population extensively. In about the same number of steps (81 compared to 78 ticks), the development of New York has been very different to that of Berlin. Although the heterogeneity of the initial population was higher in New York, the heterogeneity of the final population is lower. The reason for this counterintuitive result lies in the interaction of individuals. If the heterogeneity of the population is large, it is more difficult for individuals to find others with the same cultural identity. This impedes the formation of clusters, i.e., ghettoization. As they wander around, unhappy individuals tend to adopt the culture of their environment. Big cultural groups tend to attract individuals relatively easily, as the likelihood of getting in contact with the cultural group is relatively high. As a result, the evolution of group sizes tends to follow a self-reinforcing process – a so-called "power law". In the depicted run, this process leads to the emergence of a 'mainstream culture', which is embodied by the vast majority of the population.

In the case of "Berlin", segregation is fostered, as individuals are able to settle down near alike individuals in a relatively easy manner and without social assimilation being needed. Therefore, the persistence of different cultural groups is relatively strong.

DISCUSSION OF RESULTS

How can these results be used for political decision support in the context of multicultural societies? Basically, the simulations can improve our understanding about how the micro-behavior of agents influences the behavior of the system as a whole. Further, it is possible to generate forecasts, as done here, to predict the state towards which present societies will evolve. This application has been coined "future analysis".

Moreover, politicians may deduce which initial variables lead to the desired outcome. To this end, repeated simulations of different initial states are needed. Simulating how the setting of initial variables impacts the evolution of a city or society may help to use political instruments more efficiently. For the case of multicultural societies, such instruments might be campaigns to foster tolerance (→ with impact on *homophily*), programs of integration (→ *adaProp*) or immigration policy (→ *iniGroups*). Additionally, it is possible to derive rules of thumb. From the simulation experiments displayed, we can conclude the following:

"*A society in which heterogeneity is relatively high has a greater chance of producing a common social identity than a society with few, albeit larger, groups.*"

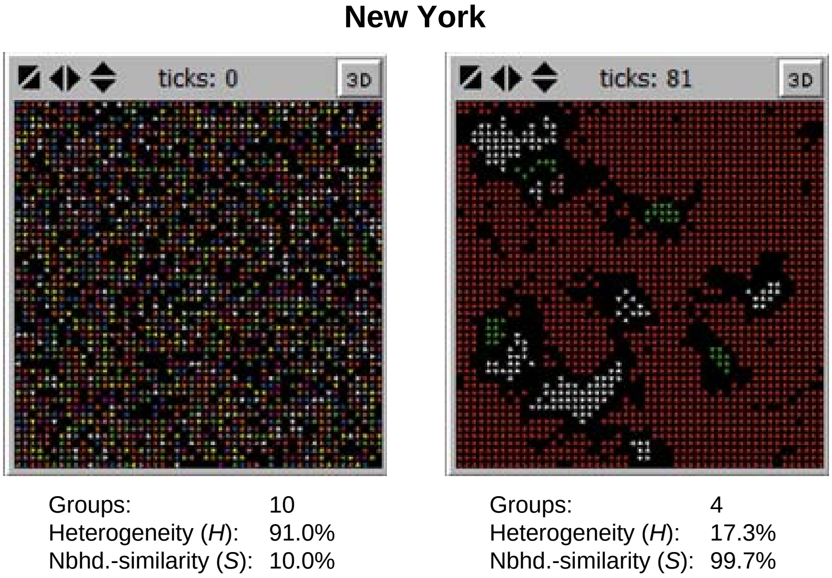

Figure 8. Overview of the Simulation Experiment "New York"

This insight may be very useful, particularly for immigration policy. If the political goal is to achieve cultural unity, immigrants should come from a variety of cultural regions. This may be new to some politicians who strive for the same goal but plead for a limitation of the cultural diversity of immigrants. In this way, ABS provides support for "future design".

In contrast to the alternative investigation procedure "creativity procedure", the analysis shows that ABS has the potential to uncover aspects of the behavior of the system which are too complex to be deduced from the behavior of agents through analytical methods, or so-called "emerging phenomena". In this way, ABS helps decision makers to gain insights which are completely new.

CONCLUSION AND OUTLOOK

The present paper investigates the potential of ABS to support political decision in multicultural societies. From the decision support perspective, the paper offers configurations to the DSS component "method" with the investigation procedure "simulation experiment" and "agent-based simulation" as well as to the DSS component "model" with an adaption of the SCHELLING model. Through the use of the investigation procedure "simulation experiment" in combination with ABS and the findings of the application to the cities "Berlin" and "New York", the presented construction hypotheses show their potential to increase the decision quality of political decisions.

Taking the *barriers* from the beginning of the paper into account, we identify the following benefits: barrier (a) ("time pressure of decisions") is relaxed, because now a simulation model exists to support the analysis and design of futures in multicultural societies. Politicians 'only' have to parameterize the model to investigate new scenarios, which has the potential to save time. The subjective influences of the barriers (c) ("space-complexity") and (d) ("time-complexity") are reduced by the automated determination of the societies' behavior, which allows for managing more space-time complexity. Summing up, the information quantity and quality increase as well (barrier (b)). It is postulated that politicians gain the information they need (Req_1 and Req_3) in a better quality. We conclude that the construction hypotheses CH_1, CH_2, CH_3 and CH_4 are temporarily accepted and propose a solution to the analysis hypothesis. Finally, the "circle closes": Politicians are supported in their attempts to identify effective political decisions to establish and preserve a functional society according to PARSON's structural functionalism (Parson, 1971).

Moreover, the paper offers contributions to social sciences and politics. It supports the understanding of typical mechanisms in societies (investigation objective “explanation”). Furthermore, the simulation model can be easily adapted to new applications (e.g. other cities or countries). Finally, the structured analysis of investigation procedures can be transferred to and used in other research problems in the field of decision support systems.

Nevertheless, the application of agent-based simulation has limitations. In the process of model design, the modeler needs information about the important characteristics of the agents, which may be derived from a particular social or political theory or be the product of empirical or experimental studies. Furthermore, models are a (desired) *simplification* of the real world’s complexity (barriers (c) and (d)). Too much simplification bears the risk of intensifying the barrier (b). Because we validated our model only against the SCHELLING model, our validation is limited (for validation problems of simulation models cf. Richardson, 1996; Sargent, 2007). Due to its high degree of abstraction, the model may be extended in various dimensions which may be relevant in reality. Such dimensions include: discrimination due to differences in housing prices or other forms of parceling. Additionally, politicians should be aware that the simulation model *reduces* uncertainty about the future, but certainly *does not remove all* uncertainty about the future of possible political actions. For the application of the investigation procedure “simulation experiment”, politicians are forced to exhibit profound knowledge in the field of ABS, which could intensify the barrier (a) because of higher time effort. Finally, we do not investigate the *whole* parameter space of the experimental factors of the cases.

In conclusion, despite the limitations of the presented approach, simulation experiments are valuable for political decision support. Due to neurophysiological limitations, it is obvious that without any methodological or technical support (of DSS), political actions bear the risk of limited decision quality. In the future, we plan to interview political decision makers as well as to conduct labor experiments to evaluate and improve our simulation model.

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